The EUROPEAN CORN BORER

Its present status and methods of control

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LOSSES IN FIELD AND SWEET CORN due to the European corn borer, in large areas or in severely infested single fields of Canada and the United States, establish this insect as among the most threatening pests of the corn plant that have invaded this country.

This bulletin tells about the habits of the corn borer and gives practicable protective measures for the farmer to employ in order to reduce injury by the pest.

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THE EUROPEAN CORN BORER: ITS PRESENT STATUS AND METHODS OF CONTROL

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THE EUROPEAN CORN BORER (*Pyrausta nubilalis* (Hbn.)) is a pest of foreign origin that was first discovered in the United States in the summer of 1917. Since that time the best efforts of Federal and State agricultural authorities have been devoted to the task of retarding its spread and of devising methods for its control. Losses due to this insect in field and sweet corn, in large areas or in severely infested single fields of Canada and the United States, show that the borer is among the most threatening pests of the corn plant that have invaded this country.

Investigations have shown conclusively that the eradication of the European corn borer in this country is not possible. It has been found

[1] The original edition of this bulletin was written by D. J. Caffrey and L. H. Worthley. The present authors have used freely the information presented in previous editions in preparing the present revision.

feasible, nevertheless, through improved farm clean-up methods and other cultural practices, to reduce the number of the borers in any given area, and thus provide the most effective available protection from general crop losses by this insect.

HISTORY OF THE CORN BORER AND ITS KNOWN DISTRIBUTION IN NORTH AMERICA

When the European corn borer was first reported and identified in North America in 1917, it was found to be causing severe damage to sweet corn in the vicinity of Boston, Mass., and to be present in a district comprising at least 100 square miles.

Subsequently it was learned that as early as 1917 the borer was also present in the vicinity of St. Thomas, Ontario, Canada, and in the districts centering around Schenectady and Silver Creek, N. Y.

The exact date on which this dangerous pest gained entrance to North America is not definitely known, but circumstantial evidence accumulated since its original discovery indicates strongly that broomcorn, imported from Hungary or Italy during the period from 1909 to 1914, was the probable means of entrance. The quarantine inspection service at ports of entry was not authorized by law until 1913, or subsequent to the probable original entry of the corn borer into this country.

Figure 1 shows the total area known to be infested in the United States by the end of 1946. The multiple-generation strain of the borer has been found over practically the entire infested area, although its proportion to the single-generation strain varies in different localities, reaching its maximum in the southern infested counties and

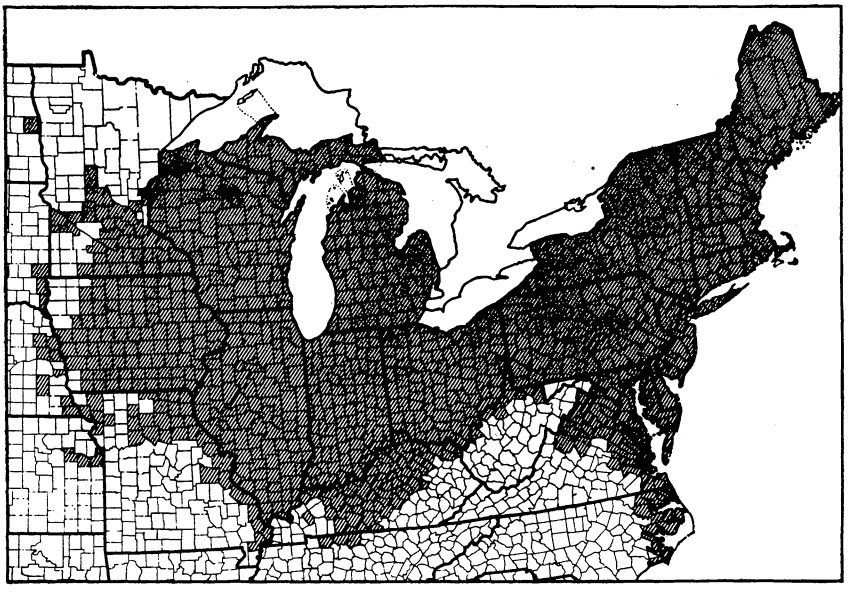

Figure 1.—Area in the United States known to be infested by the European corn borer up to the close of 1946.

diminishing toward the north. Wherever the multiple strain is present the number of generations is established by the nature of the environment. A short season in the northern portions of the area is conducive to a single generation, while the long season on the eastern shore of Virginia allows the development of three generations annually. The insect has been found at several isolated points at some distance from the area of general infestation.

The corn borer moths are strong flyers, and it is believed that the extension of the infested area each year is caused principally by flight. Experiments have shown definitely that corn borer moths are able to fly for a distance of at least 20 miles, and judging from their general habits it is probable that they can and do fly greater distances. Large bodies of water do not check their flight, as the moths have been seen to alight on the surface of the water and again take flight. Experiments have also shown that the moths were able to reach cornfields surrounded by high hills or woodlands. During windy periods flight is usually with, or in the direction of, the wind.

It is also known that when hidden in cornstalks, the larvae can survive long periods of submersion in fresh or salt water. This fact, plus the fact that cornstalks are known to have been borne long distances in the currents of rivers, lakes, and the ocean, indicates that many of the new infestations along the North Atlantic seaboard, in the Great Lakes region, and along the river courses of the present infested area have had their origin in water-borne infested cornstalks or other infested plant material.

CORN, THE FAVORITE HOST OF THE CORN BORER IN THIS COUNTRY

Corn is infested and injured (fig. 2) by the larvae, or borers, of the European corn borer to a greater extent than any other crop attacked by the insect in this country. The borer attacks field corn (both dent and flint), sweet corn, popcorn, and corn planted for fodder or silage. Years of experiments and observation indicate that corn (Indian corn, or maize) is the favorite host of the insect in North America, as it is in Europe.

In the Lake States area, comprising western New York and infested States west of New York (fig. 1), corn was practically the only cultivated plant that had been injured or infested to any extent by the corn borer up to the end of 1940. A light infestation has been found in some of the more common large-stemmed weeds and grasses growing among the corn or along the margins of badly infested cornfields. Careful examinations under these conditions have revealed the presence of the borer in pigweed (*Amaranthus* spp.), smartweed (*Polygonum* spp.), cocklebur (*Xanthium* spp.), barnyard grass (*Echinochbloa crus-galli*), lambsquarters (*Chenopodium* spp.), foxtail (*Chaetochloa* spp.), panic grass (*Panicum* spp.), and similar plants.

The fact should be emphasized that in the Lake States area these corn borer infestations in weeds have been confined usually to infested cornfields or their margins and are most often caused by borers seeking shelter in such plants. Several native borers very similar in appearance to the European corn borer (pp. 43–46) are found frequently in vegetables, field crops, flowers, shrubs, or weeds. Only rare instances of corn borer infestations in weeds growing at a distance from

Figure 2.—Ear and stalk of dent field corn showing typical injury by the European corn borer.

corn have as yet been observed, although special and extensive examinations have been made to determine this point.

Under conditions of favorable exposure in the Lake States infestations have been observed in some of the cultivated crops and flowering plants, including broomcorn, soybean, millet, buckwheat, oats, potato, pepper, sorghum, dahlia, and cosmos.

In the Eastern States area, comprising eastern New York and the infested States along the Atlantic seaboard (fig. 1), corn is the favorite host of the corn borer, but where two generations predominate in

this section the pest commonly lays its eggs upon and attacks many other plants, including vegetables, field crops, flowers, and weeds. Rhubarb (fig. 3), beet, celery, bean (especially lima, fig. 4), pepper, oat, millet, dahlia, aster, gladiolus (fig. 5), chrysanthemum (fig. 6), zinnia, cosmos, hollyhock, and many different kinds or species of large-stemmed weeds and grasses are often injured severely by the corn borer in this section. In fact, over 200 kinds or species of plants in this area have been found to be infested. Many of these plants serve as shelter for the borers, rather than as food, and are infested sometimes by the borers which "overflow" from corn and other favorite host plants growing nearby.

Why the borer infests so many different kinds of plants more commonly in the Eastern States than in the Lake States, where two gen-

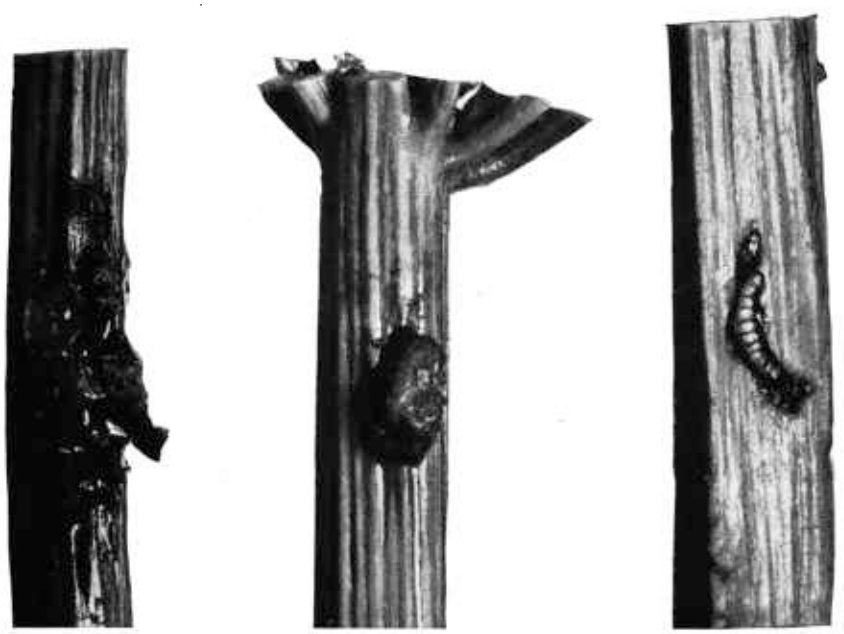

Figure 3.—Rhubarb stems infested with the European borer.

erations also occur, is not definitely known. However, where two generations occur the moths developing from the overwintering borers begin laying eggs much earlier in the season than where one generation occurs, and the next brood of moths lays eggs later than do the moths of the single generation. Hence the single-brood moths find corn in abundance and in an attractive condition, and lay their eggs on it rather than on plants that are less desirable as food for their larvae. Both broods of the multiple-generation moths find many kinds of plants attractive, while there is often a relatively small acreage of corn in a condition attractive to them for egg laying. In those sections where more than two generations occur, similar considerations of host-plant and borer development probably determine the number of different kinds of plants infested. The first generation on the Eastern Shore of Virginia, for instance, is found almost exclusively in potatoes, since there is a scarcity of corn in an attractive

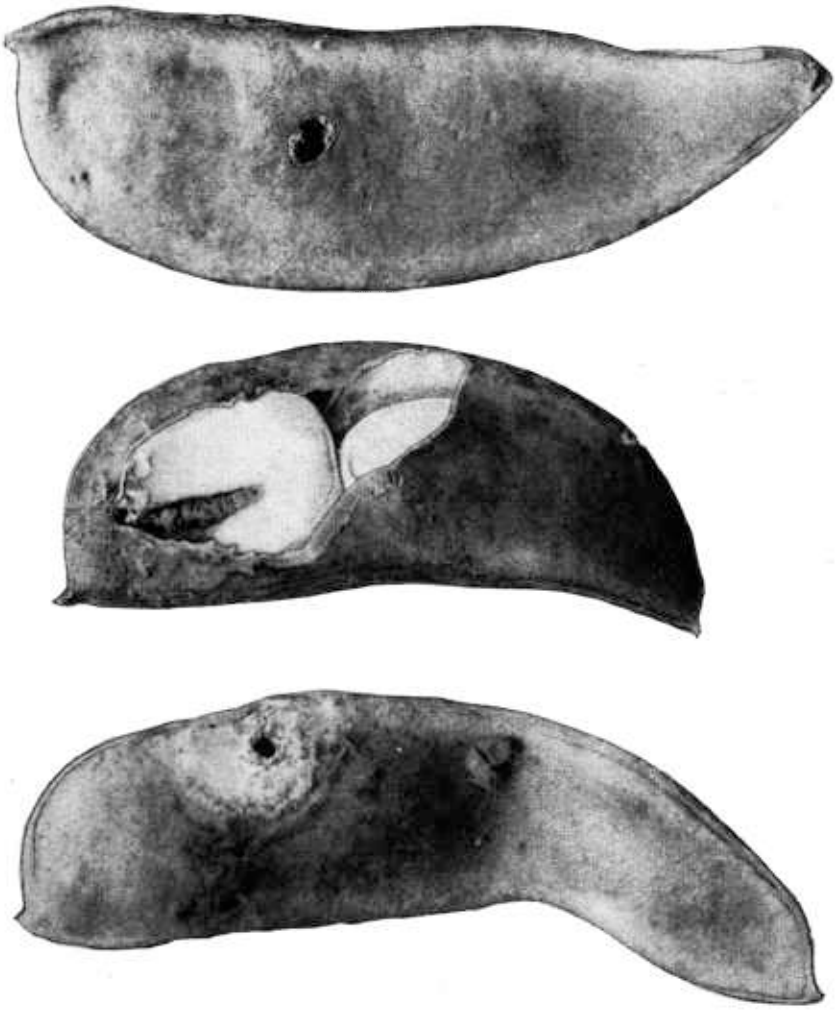

Figure 4.—Lima bean pods infested by the European corn borer. One pod cut open to show the borer feeding on the bean within. Borer entrance holes are shown in the other two pods.

condition for oviposition during the egg-laying period of the moths that develop from the overwintering borers.

CHARACTER OF INJURY TO CORN CAUSED BY THE CORN BORER

The European corn borer is essentially a boring insect and its greatest injury results from the tunneling and feeding of the larvae within the stalk (fig. 7), ears (fig. 8), tassel, midrib of the leaf, brace roots, stubble, and in fact in practically all parts of the corn plant except the fibrous roots. In addition the larvae feed to a slight extent upon the surface of the plant, particularly upon the leaf blades (fig. 9), tassel buds, husks and silks of the ear, and leaf sheaths.

The character of the injury inflicted depends on the stage of development of the corn plant when attacked. Soon after hatching, the borers begin migrating to various parts of the same plant or to other plants in the vicinity. The developing whorl, when available, is a favorite feeding location for newly hatched larvae. If the attacked plant is just developing a tassel, some of the small borers enter the tassel buds and feed within, while others feed on the surface of the tassel buds and protect themselves with a slight silken web. If the infestation occurs at time of pollen shedding, accumulations of the pollen at the ligules supply favorable material on which the larvae feed. Later they tunnel within the tassel stem and its branches, often

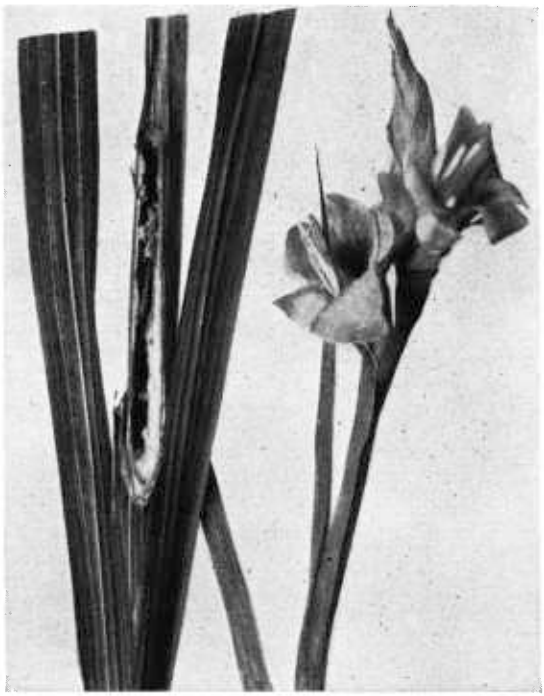

Figure 5.—Gladiolus stems showing infestation by the European corn borer.

causing it to break over. These broken tassels (fig. 10), with bunches of sawdustlike borings at the breaks, are the most conspicuous signs of corn borer infestation in fields of growing corn, although many of the infested corn plants may not show this particular injury. The borers may continue tunneling downward into the main stalk, or they may leave the upper part of the plant and enter it or neighboring plants at points lower down. Some of the newly hatched borers, instead of feeding upon or within the tassel buds and tassel stalks, enter the stalk directly at some lower point.

The borers usually enter between the leaf sheath and stalk or between the stalk and the base of the partly developed ear in case the plant has advanced to that stage of development. As they gradually

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Figure 6.—European corn borer injury to stem and flower of greenhouse chrysanthemum. Stem cut open to show borer within and type of injury to stem and flower head.

Figure 7.—Hill of sweet corn ruined by the European corn borer. Stalks sectioned to show extensive damage within. Borers averaged 37 per plant in this field.

increase in size their tunnels are made larger, and the borers work upward or downward, according to their individual preferences, although the majority work upward. Small holes in the plant with bunches of sawdustlike borings at or below the holes indicate the section in which the borer is at work.

The tunneling of one or two borers in a stalk does not always cause

Figure 8.—European corn borer injury to grain and cob of flint field corn. Cobs cut open to show borers within. Every stalk and ear in the field from which these ears were harvested was infested.

appreciable damage; but when several or many are present within the same stalk, as frequently occurs, it becomes reduced to a mere shell and is filled with fragments of the frass or castings of the borers. Such injury may cut off much of the supply of nutriment from the ear and greatly weaken the stalk, which eventually breaks over. It has been found that corn plants suffering from severe corn borer injury ripen much earlier than uninjured or slightly injured plants.

At any stage of their development the borers may enter the ear directly at its tip, base, or side; or they may enter it indirectly through the short stem, or shank, by which the ear is attached to the stalk, in which case this stem is frequently so weakened by the injury that it breaks over before the ear has completed its development. Ordinarily the ear is entered at its tip by small borers which feed first upon the silks or the tender portion of the husk, and then work their way down into the cob and grain (fig. 11).

The injury to stalks and ears done by the corn borer may be still further increased by decay, which often follows the work of the borers.

Figure 9.—Injury by young corn borers to leaf blades of corn.

CHARACTER OF INJURY TO PLANTS OTHER THAN CORN

The injury to plants other than corn is of the same general character as that to corn, except that in some instances only particular parts of the plants appear to be preferred for food or shelter.

The stems or stalks of celery, rhubarb (fig. 3), potato, hop, oat, barley, buckwheat, hemp, cotton, dahlia, chrysanthemum (fig. 6), gladiolus (fig. 5), aster, zinnia, cosmos, geranium, and other plants are entered and tunneled by the borers, and the borers are sometimes found in the fruits or flowers of certain plants, notably tomato, pepper, cotton, hemp, dahlia, chrysanthemum, and gladiolus.

The stems and leaves of beet, Swiss chard, and other plants are preferred by the borers when attacking these plants. The roots of beet are entered occasionally.

In beans the borers are usually found in the stalks, pods (fig. 4), or green beans.

Not only do the borers cause actual loss by their injury to these crops, but there is also the likelihood that such products, when distributed

through commerce, may serve as carriers of the pest to new localities.

The presence of the European corn borer in weeds and wild grasses is not of itself commercially important, but it affords abundant opportunity for the multiplication and spread of the pest.

Figure 10.—Broken corn tassel showing injury caused by European corn borer larvae.

DESCRIPTION AND SEASONAL HISTORY OF THE CORN BORER

The single-generation strain of the European corn borer passes the winter as a fully grown borer, or "worm," inside its tunnel in the stalk, stubble, or ear of corn, or in some weed or other plant material growing close to corn. The presence of the borers may be indicated by small holes on the surface of the infested plants. These holes are usually plugged with the castings of the borers. When these stalks, stubs, etc., are split open, the borers usually are found within. At this

time the borer is nearly an inch long and one-eighth inch thick (fig. 12). The head is dark brown or black. The upper surface of the body ranges in color from light brown to dark brown or to pink. Each division of the body bears a row of small dark-brown spots, while

Figure 11.—Typical injury by the European corn borer to the grain and cob of sweet and flint corn. Borers shown feeding in natural position. The inside of the cobs was also badly tunneled by the borers.

several narrow dark-brown or pink lines extend lengthwise of the body. The underside of the body is flesh colored and is without markings.

As soon as warm weather begins, in April or May, the borers may leave the shelters occupied during the winter and bore into more suitable places to pass the resting stage.

Late in May or early in June the borer cuts a small circular opening from its tunnel to the surface of the plant in order to provide an exit

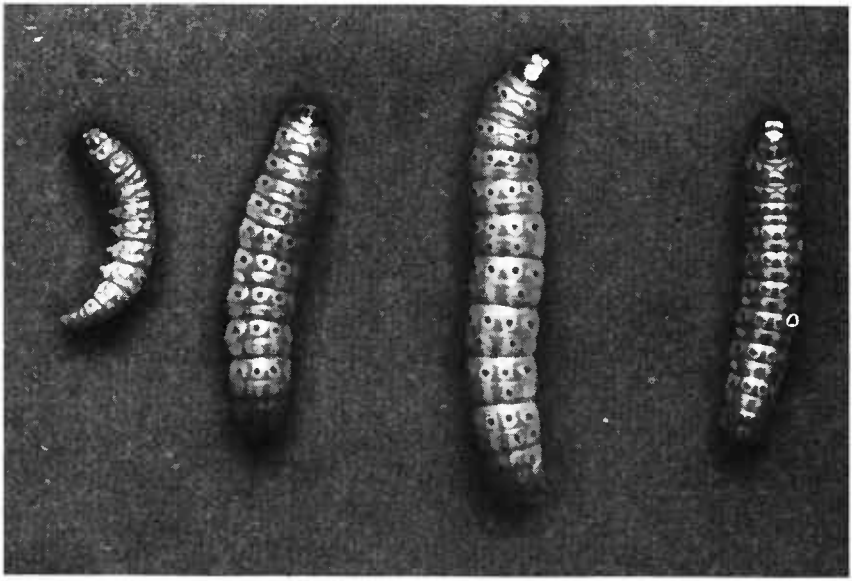

Figure 12.—Full-grown larvae of the European corn borer. The borer passes the winter in this stage. Twice natural size.

for the future moth. It then closes this hole with a thin portion of silk and retreats into its tunnel to a point near the last feeding or shelter place, where it usually spins a thin cocoon. Inside this cocoon the borer changes into the resting stage, or pupa (fig. 13).

The pupa, or resting stage, is shuttle-shaped, ranges in color from light brown to dark brown, and is from one-half to five-eighths of an inch in length. After a period of from about 10 to 14 days the skin of the pupa splits, and the moth, or adult, comes forth and is present in the fields from late in June to early in August, under average weather conditions.

The female moth (fig. 14, *A*) has a robust body and measures about an inch from tip to tip of the wings. The general color is variable and includes all shades from pale yellow to light brown. The outer third of both the forewing and the hindwing is usually crossed by two narrow zigzag lines darker than the rest of the wing. The male moth (fig. 14, *B*) has a longer, more slender body, is slightly smaller in wing

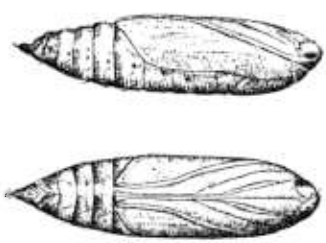

Figure 13.—The resting stage, or pupa, of the European corn borer. About twice natural size.

expanse, and is usually much darker than the female. The general color ranges from pale to dark brown, sometimes with a blue tinge. The outer third of the wing is usually crossed by two narrow zigzag

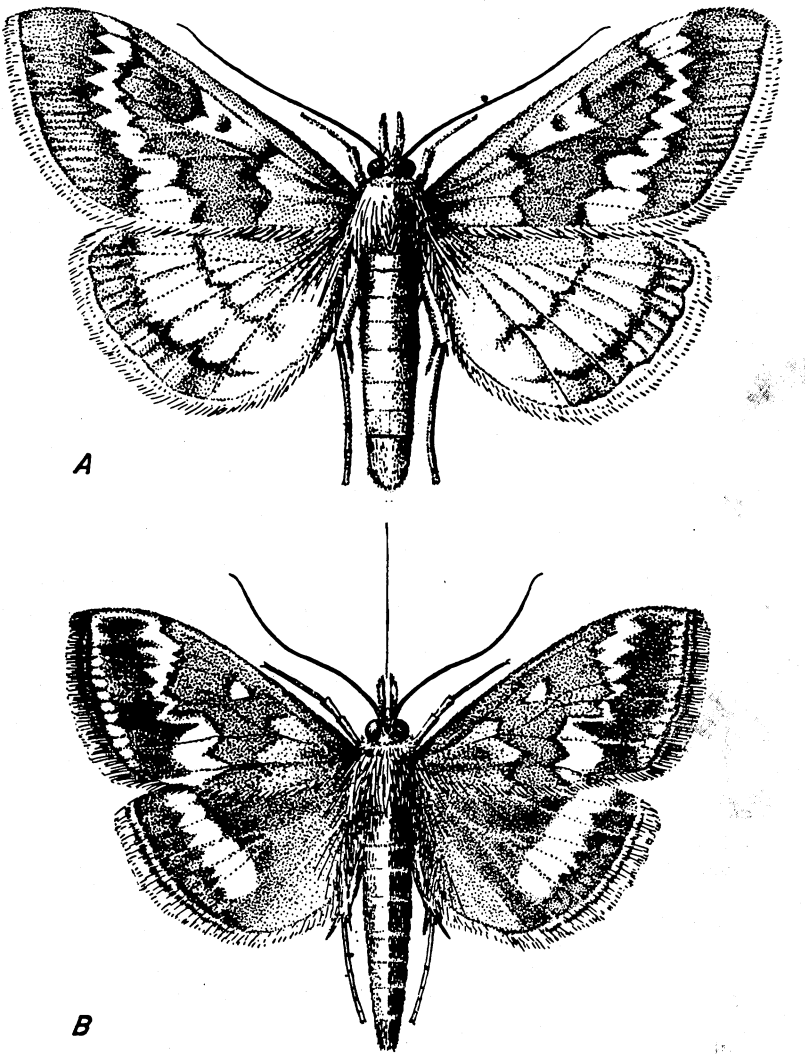

Figure 14.—Moth or adult stage of the European corn borer. *A*, Female moth; *B*, male moth. Not quite twice natural size.

streaks of pale yellow, and there are frequently small pale-yellow areas on the forewing.

The moths of the European corn borer resemble several other kinds or species of moths so closely that it is difficult if not impossible for the average person to distinguish between them.

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Soon after emergence the females begin to lay their eggs. They remain quiet during the day, hiding in patches of weeds and grass or underneath the leaves of other plants. During the evening and sometimes throughout the night, when weather conditions are favorable, they fly from plant to plant, laying their eggs in flat, irregularly shaped masses (fig. 15). The number of eggs laid by each female moth averages about 400, although the number varies greatly, and a maximum of over 1,900 has been observed. The moths live from 10 to 24 days.

There are usually from 15 to 20 eggs in the average egg mass. As many as 162 eggs have been found in a single mass, although eggs

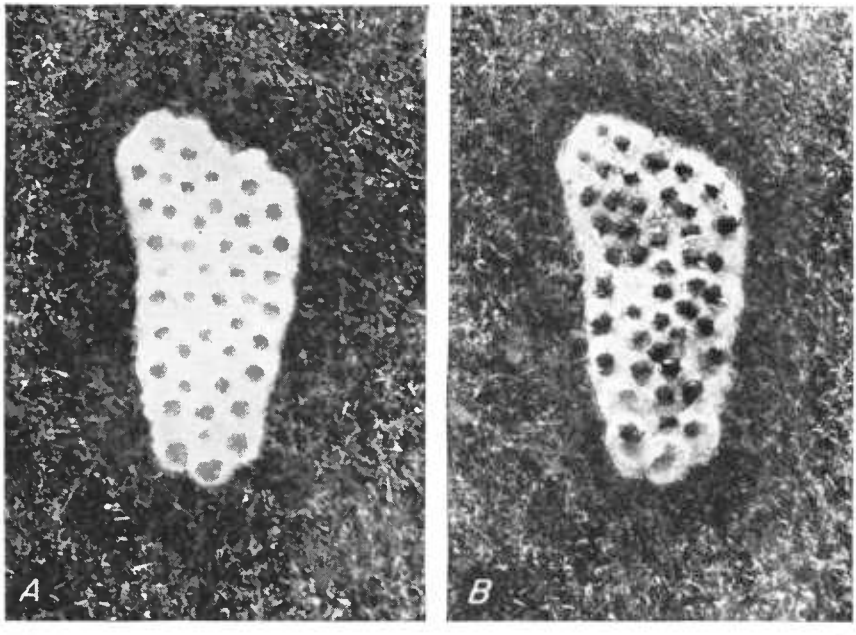

Figure 15.—Egg masses of the European corn borer: *A*, Newly laid egg mass; *B*, same egg mass in the black-head stage, just before hatching. Enlarged 7 times.

deposited singly may be observed. These egg masses are laid principally upon the under side of the corn leaves, although they are sometimes laid on the upper side of the leaf, on the stalk, or on the husk of the ear. Each egg is about half the size of an ordinary pinhead, and in the clusters the eggs overlap like fish scales. By closely examining the under surface of corn leaves it should be possible for any person to find these egg masses where the moths are numerous.

The egg is nearly flat and is white when first laid but later changes to pale yellow, becoming darker just before the young borer comes out.

The eggs hatch in from 4 to 9 days, depending on weather conditions. The newly hatched borer is about one-sixteenth of an inch long and has a black head and a pale-yellow body that bears several rows of small black or brown spots. During its growth the borer changes its skin, or molts, five or six times, gradually increasing in

size with each change until at last it reaches the stage in which it passes the winter.

In the North Central States most of the borers become nearly full-grown by the middle or latter part of August if weather conditions are normal. The borers continue to feed, or bore, however, at intervals until cold weather stops their activities in October or November. They remain in a dormant condition throughout the winter within their tunnels in the cornstalks, stubble, cobs, or other plant remnants.

The multiple-generation strain, which predominates in the eastern and southern parts of the infested area, develops one or more generations per year in accordance with the general type of environment and the seasonal conditions experienced from year to year within the different environments. In the more northern portions of the Eastern States, including parts of New England, when weather conditions are unfavorable for the borer only a partial second generation develops. Favorable weather conditions produce practically a complete second generation. In the more southern areas additional numbers of generations develop. Two generations and sometimes a partial third occur in New Jersey, while on the Eastern Shore of Virginia the corn borer has three generations annually. In the New England area, in general, the overwintering borers are entering the pupal stage during May and early in June. The adult moths emerge during June and early in July and lay their eggs during that period. The borers hatching from these eggs are considered to be the first-generation borers. Part of these borers (the percentage depending on weather conditions) become fully grown during the period extending from late in July to late in August and enter the pupal stage. The moths emerge from these pupae during August and early in September and lay their eggs throughout these months. The borers hatching from these eggs constitute the second or overwintering generation which develops in the same manner as that described for the first-generation borers. They become fully grown before the appearance of cold weather. These second-generation borers, together with such of the first-generation borers as did not transform, pass the winter in a dormant condition within the stalks, stubble, and cobs of corn and in the stems of a great variety of vegetables, flowers, weeds, and large-stemmed grasses.

The discussion in the preceding paragraph applies particularly to the seasonal development of the corn borer in the district immediately west and north of Boston, Mass. In the more southern infested areas the development starts progressively earlier, the moths emerging from the overwintering resting stage in New Jersey from the middle to the latter part of May and in Virginia during the latter part of April. The average egg-laying periods for the three generations on the eastern shore of Virginia start early in May, late in June, and the second week in August, respectively.

CROP LOSSES CAUSED BY THE BORER

IN THE UNITED STATES

When the corn borer was first reported in the vicinity of Boston, in 1917, it was already causing severe damage to sweet corn. The degree of injury increased up to 1922 as the infested area extended, and not only sweet corn but field corn was badly damaged, approxi-

mately 20 percent of the ears, on an average, being infested and some small acreage showing an infestation of from 80 to 100 percent of the ears. Many truck and garden crops, also, were damaged. From this time on through 1926 the degree of infestation decreased owing to unfavorable weather and the enforcement of State clean-up laws.

From 1927 to 1930 there was a new increase in intensity as well as in the extent of infestation, resulting in commercial damage in southern Massachusetts, Rhode Island, Connecticut, and eastern Long Island, the infestation covering all of eastern and southern New England and large parts of New Jersey. By 1933 the losses in Connecticut to field corn in places were as high as 56 percent, and some fields of sweet corn were plowed under as a total loss.

Heavy concentrations of borer populations in sweet corn in Connecticut have continued, the average population of almost 20 borers per plant in early-market sweet corn in New Haven County in 1939

Figure 16.—A field of dent corn ruined by the European corn borer. Hightstown, N. J., 1938.

being the heaviest infestation thus far observed in the United States. Other areas of severe damage to sweet corn are in the Hudson and Connecticut River Valleys in New York and Massachusetts, respectively. Damage to field corn in central New Jersey in 1938 (fig. 16) was as severe as any previously observed in this type of corn in the United States, and conditions were comparable to those observed in Ontario, Canada, during the very severe outbreak there in 1926. Hundreds of acres sustained a loss of over 50 percent of the crop, and some fields were practically ruined.

By 1940 the corn borer was causing considerable damage to corn along the Atlantic Coast as far south as northeastern North Carolina and appreciable crop losses of varying intensity now occur annually in this section.

In western New York, northeastern Ohio, and southeastern Michigan, corn was seriously injured first in 1926, with crop losses as high as 25 and even 40 percent in the most severely infested fields. In these districts and in Pennsylvania nearly four times as many borers were present as at the same time in 1925. As a whole, in the States bordering Lakes Ontario, Erie, and Huron there was a yearly increase in the

intensity of infestation from 1926 to 1939, with the exception of 1930, 1933, and 1934, when weather conditions were not favorable for the insect. In 1931 the sweet corn in some fields along Lake Ontario in New York was discarded because the canning factories declined to accept the crop. Beginning in 1935, populations built up rapidly in the early-market sweet corn around the western end of Lake Erie and reached an average intensity of more than 17 borers per plant in this type of sweet corn in Lucas County, Ohio, in 1938, with consequent severe crop losses.

Since the beginning of 1942 sweet corn in the localities of Cincinnati, Ohio, Indianapolis, Ind., and Kankakee County, Ill., has suffered seasonal injury from the pest. The growing of the crop has been practically abandoned in the vicinity of Indianapolis and in Kankakee County, Ill., where most of the early sweet corn was destroyed by the borer in 1942 and 1943. Commercial damage to field corn has been common in Indiana since 1942 and in Illinois since 1943. In eastern Iowa in 1944 and 1945 a number of fields were severely injured. In 1945 the loss caused by the borer in the United States was estimated at $36,700,000.

IN CANADA

At the close of 1925 the infestation in Ontario, Canada, had become so serious that in counties where the best dent corn in Canada had formerly been grown the corn crop throughout an area of at least 400 square miles was completely ruined. In 1926 in an area of about 1,200 square miles the corn acreage had been reduced to about 10 or 15 percent of that of 1922. Many fields suffered a complete loss of the crop, and losses of 75 percent were common. Less favorable weather for the borer and compulsory clean-up of the fields since 1926 have improved conditions from year to year, although the infestation in Kent and Essex Counties in Ontario in 1937 was the third highest on record.

IN EUROPE AND ASIA

The European corn borer has long been recognized in Europe and Asia as one of the worst pests attacking corn, millet, hops, hemp, and similar crops. Although it seldom causes severe damage in those Old World areas where all infested corn remnants and other crop remnants are customarily destroyed by burning or plowing or are used for feed or fuel, it causes heavy losses in areas where large quantities of corn remnants are customarily left on the farms from year to year, as is now commonly done in the American Corn Belt.

NATURAL ENEMIES OF THE CORN BORER

NATIVE INSECT PARASITES

Although several native natural enemies of the European corn borer have been recorded from this country, they do not usually attack the pest in any important numbers and, from present indications, cannot be relied on to hold the borer in check. Extensive studies of the native insect parasites of the corn borer have shown that only a fraction of 1 percent, on an average, were being destroyed by them, although 24 different kinds of parasites were attacking the pest in its various stages.

INTRODUCED INSECT PARASITES

Since the native insect enemies of the corn borer have been of little consequence, it seemed important to investigate the foreign parasites that were preying on the corn borer in its native homes, particularly in France, Italy, Belgium, and Hungary, and in various countries of the Orient. As a first step, however, it was necessary to make careful studies of such parasites in the countries mentioned. These studies revealed several kinds of parasites that were helping to check the ravages of the pest. After it had been determined that

Figure 17.—Liberating foreign parasites of the European corn borer.

none of them could by any possibility become harmful to plants, they were sent to the United States and liberated (fig. 17) close to cornfields, or infested plants, where the corn borer was most numerous. Special precautions were taken to prevent the introduction with them of natural enemies of the parasites (known as hyperparasites).

The importation of parasites from Europe and from the Orient was supplemented by extensive breeding work under laboratory conditions in this country, as a result of which these imported parasites were greatly increased in numbers before being liberated in infested fields.

From foreign importations a total of over 2,000,000 adult parasites have been released in the infested area of the United States. These have been supplemented with over 3,000,000 adults obtained through laboratory breeding programs and nearly 1,000,000 adults from domestic field collections in Massachusetts, Connecticut, and New Jersey,

where five species of imported parasites have become established. Three of these have been so numerous that they could be obtained more effectively from the field than from either importation or laboratory breeding.

Twenty-one different kinds of parasites have been released over the infested area, and five of them have responded very well to conditions prevailing in different localities in which they have been under observation. In the Lake States one of the promising species is a tachinid fly, *Lydella stabulans* var. *grisescens* R. D., which restricts its activities to sections bordering marsh areas of Lake Erie. Although it is abundant only in a narrow band in these sections, fields in which over half of the borers have been killed by this fly were commonly observed, and numerous fields have had over three-fourths of their infesting corn borers destroyed by this parasite. One other imported parasite, *Eulophus viridulus* Thoms., is well established and widely distributed over a large part of Ohio, Indiana, and Michigan, but has not yet increased to effective numbers. *Chelonus annulipes* Wesm. is established in the Lake States but its numbers are so small and its distribution so restricted that at present its contribution to control is negligible.

Very recent releases of the important parasite *Macrocentrus gifuensis* Ashm. in the Corn Belt States have resulted in satisfactory initial establishment, particularly in Wisconsin and Iowa, but it is too early to draw reliable conclusions on the results of this work.

In the Eastern States five promising species, *Lydella stabulans* var. *grisescens*, *Horogenes punctorius* (Roman), *Macrocentrus gifuensis*, *Chelonus annulipes*, and *Phaeogenes nigridens* Wesm., are well established in one or more of the liberation sections, and parasite populations are continually increasing, particularly in eastern Massachusetts, central Connecticut, the lower Hudson River valley in New York, central New Jersey, southern Delaware, southeastern Virginia, and northeastern North Carolina.

The Parasites Cannot Harm Plants

It should be understood that none of these parasites can, through any chance, become harmful to plant growth, as they are parasitic exclusively on insects and never depend on plants for food.

Parasites Only One Factor of Control

Although strenuous efforts have been made to import and establish parasites in the North American areas infested by the corn borer, it is not certain that they will prove to be effective aids in control. Even with the best of success, parasites cannot be expected to exert an important effect on the borer every year and throughout its range. Every effort should be made to control the corn borer by the other methods discussed in this bulletin.

BIRDS AND OTHER ENEMIES OF THE BORER

With the exception of feeding by woodpeckers in some localities, birds are not known to have an important influence in reducing the numbers of the corn borer in the infested areas of the United States. In some of the large cornfields in the Lake States and in many of the small garden patches in the Eastern States the downy wood-

pecker (*Dryobates pubescens* (L.)) has been known to remove and destroy from 17 to 95 percent of the borers in cornstalks and other host or shelter plants. In the winter of 1932–33 woodpeckers destroyed an average of 30 percent of the borers in 20 cornfields examined in Ohio and Indiana.

Robins, grackles, blackbirds, starlings, crows, and Mongolian pheasants also are known to feed on the corn borer. Careful observations in connection with plowing experiments in Ohio, in cooperation with States authorities, showed that robins and other birds were devouring at least 15 percent of the borers that had crawled back to the soil surface after infested cornstalks had been plowed under. Canadian authorities report that crows removed and devoured about 25 percent of the corn borers from broken-over cornstalks in certain badly infested fields of Essex and Kent Counties, Ontario, during the winter and spring of 1926–27.

Various insect predators, and spiders, mites, rodents, and skunks have been observed preying on the corn borer in restricted instances or localities, and in some cases under favorable conditions the insect predators may have been an important factor in keeping down the borer population.

DISEASE

The corn borer is comparatively free from attack by disease. However, in 1931 investigations were started with a fungus, *Beauveria bassiana* (Bals.) Vuill., which was known to attack the borer in the Orient. Experiments to date have shown that the corn borer is very susceptible to this disease. Spores of the disease were dispersed in test spots throughout the corn borer-infested districts. Although a few borers killed by the disease have been found, there are no present indications that this fungus will become an aid in the natural control of the pest.

METHODS OF CONTROLLING THE CORN BORER

Experience in fighting the European corn borer has indicated that the pest may be controlled most effectively by utilizing or destroying all parts of infested plants each year before the insects develop from the borer stage into the moth, or adult. Under practical farm conditions this means that all infested plants must be disposed of principally through any one of the following methods or by a combination of such methods: (1) Feeding to livestock direct, or as silage, or as finely cut or finely shredded feed; (2) plowing under deeply and cleanly; and (3) burning completely.

In presenting the following information on methods of controlling the corn borer, attention is again directed to the point that the habits of the insect in the North Central States area differ in some important respects from its habits in the Eastern States. In the North Central States corn is practically the only plant directly attacked by the corn borer, and therefore the main control effort should be directed against corn, whereas in the Eastern States the corn borer attacks, in addition to corn, such a great variety of vegetables, field crops, flowers, and large-stemmed weeds and grasses that the remnants of these additional plants must be included in farm disposal or clean-up operations. Particularly important in the Eastern States, are the large areas of

weeds growing in waste or unoccupied lands. Such areas must be cleaned up by burning while the plants are dry or by the use of weed killers while the plants are in a green, succulent condition.

It is desirable, whenever agricultural conditions permit, to dispose of infested cornstalks and other infested plant residues in the fall, especially in fields, gardens, or weed areas which cannot be plowed or otherwise handled effectively in the spring. This applies particularly to fields in which the rotation calls for seeding small grains in the spring and in which the character of the soil is such that it cannot be successfully prepared for small grains or other crops by spring plowing.

Since the corn borer develops into the flying and egg-laying stage late in the spring or early in the summer, all infested corn plants and corn remnants should be disposed of before that time in order to prevent the multiplication of the pest. The spring development of the borer and the date by which the disposal of all corn residues should be completed are progressively later from south to north. Farmers should therefore obtain this date from their respective State Agricultural Experiment Stations.

Although many of the foregoing recommendations require a radical departure from present farm practices, such changes appear necessary where infestation is serious, if the pest is to be controlled.

Community-wide effort is essential because the moths can fly from field to field and thus spread an infestation long distances. The moths emerging from a single uncleaned or poorly cleaned, infested field can reinfest many other fields that have been properly cleaned up.

It should be emphasized that the particular clean-up method adopted is optional so long as the infested plants and the crop remnants are disposed of by being fed to livestock, by being plowed under cleanly, by being burned entirely, or by any other method that kills the borers contained in the remnants.

Each field presents a separate problem, and clean-up methods will naturally vary according to the type of farming practice used.

FEEDING INFESTED PLANTS TO LIVESTOCK

The feeding of infested plants to livestock is one of the most effective methods of fighting the corn borer and is also a very desirable farm practice. The food value of the fodder is not noticeably injured by the corn borer except in cases of severe infestation. Infested corn plants may be fed as silage, or direct from the field, or in the form of finely shredded or finely cut fodder. When properly carried out, any of these methods of disposal results in the destruction of nearly all the borers contained in the plants.

To obtain the best results with the silo, under corn borer conditions, the infested plants should be cut as close to the ground and as early in the season as possible. Any borers that escape the silage cutter are destroyed in the silo.

Infested cornstalks must be cut into pieces not longer than half an inch, in order that practically all the borers may be killed. This precaution is particularly important in instances where the silage is not placed directly in the silo or is not fed soon after it is cut.

The use of special, low-cutting attachments for corn binders (fig. 18), which are obtainable from some of the larger implement manufacturers, is strongly recommended. Experiments have shown that when cornstalks are cut about the middle of September at least 3 percent of the borers are left in stubble 3 inches high, and at least 7 percent are left in 6-inch stubble. In general, the number of borers living in the stalk (fig. 19) below any given height triples between

Figure 18.—Corn binder with low-cutting attachment at work in a field infested by the corn borer. Such low cutting, if cleanly performed, results in practically 100 percent of the borers being removed from the field in the fodder or being placed in the shock, where they may be destroyed in the spring clean-up. (Illustration from Bureau of Plant Industry, Soils, and Agricultural Engineering.)

September 15 and the first week of November, as the borers move down through the stalk toward winter quarters.

A home-made sled harvester has been developed, in cooperation with the Bureau of Plant Industry, Soils, and Agricultural Engineering, which effectively cuts at the ground level the stalks intended for silage or fodder. This implement is particularly adaptable to acreages too large for hand cutting and too small to warrant the purchase of a corn binder with low-cutting attachment.

It is plain that where cutting is the accepted farm practice the corn should be cut as low and as early as possible. Such low cutting also helps in doing a clean job of plowing later on and facilitates any other clean-up methods used.

In actual practice the use of a short-handled, heavy hoe (fig. 20) has been found effective and practicable in many instances where the corn is to be cut by hand. By this method the corn can be cut at, or

Figure 19.—Stubs showing corn borers concentrated near the ground level. One stub is cut open to show the borers within; the other shows the entrance holes made by the borers. This picture illustrates the necessity for cutting cornstalks close to the ground.

very near, the surface of the ground. The use of hoes for cutting corn has come into increasing favor with farmers, particularly in the smaller fields, where remarkably good jobs have been performed with this tool.

Feeding Direct From the Field

When infested cornstalks are fed direct (fig. 21) without previous cutting or shredding, the uneaten parts should be collected and destroyed, preferably by burning, unless they are trampled completely by livestock and thoroughly mixed with the manure of the feed lot.

It is dangerous to allow large quantities of cornstalks to accumulate in barnyards and feed lots (fig. 22) unless they are treated, before moth emergence each year in the way described in the preceding paragraph. Examinations of cornstalks gathered from barnyards and from the surface of manure piles on typical farms have shown as many as 256 borers per 1,000 linear feet of stalk. It is

Figure 20.—Short-handled hoe for use in cutting corn by hand.

apparent that such stalks may constitute an important source of corn borer infestation in the following season. No living borers were found in thoroughly trampled cornstalks or in finely cut or finely shredded corn fodder that had been used for feed or bedding.

Effect of Embedding or Trampling Infested Cornstalks in Manure

Experiments and observations on infested farms have shown in general that many corn borers survive in cornstalks placed in the ordinary farm manure pile and migrate in large numbers from the piles to seek shelter in surrounding objects. It is therefore strongly recommended that farmers avoid placing infested material in manure piles, that all manure from piles containing infested material be cleanly plowed under early in the spring before larvae begin to

Figure 21.—A common source of infestation by the European corn borer: Remains of whole cornstalks fed direct to livestock in pasture and feed lot. These remnants should be raked into piles or windrows and burned.

Figure 22.—A barnyard feed lot that was not sufficiently trampled by livestock. Approximately 15,000 exposed stalks contained nearly 39,000 corn borers. All dry parts of such stalks should be collected and burned, unless completely trampled by animals and thoroughly mixed with the manure.

migrate in large numbers, and that all plant remnants be removed from barnyards and destroyed or buried.

The number of borers that survive in properly handled feed lots was observed to be so small that any treatment of the stalks in addidition to their being trampled by animals is believed to be unnecessary. It is essential, however, that the trampling be thoroughly done and that no dry or unbroken sections of cornstalks be left on the surface of the feed lot. When all plant remnants are thoroughly mixed with manure by trampling, no other treatment need be given. The time of trampling seems unimportant, except that it should be completed before the emergence of the moths. If the stalks in feed lots have been insufficiently trampled and still contain living borers, they should be completely plowed under before moth emergence.

It should be emphasized that under ordinary farm conditions the large uneaten parts of corn fodder should not be put in the manure unless they can be completely trampled in by livestock.

Husker-Shredder Machines Very Effective in Killing Borers

Shredding or cutting corn fodder into fine pieces, as is ordinarily done by husking and shredding machines, kills from 95 to 98 percent of the borers and renders the fodder more acceptable to livestock. This result was obtained in tests with several types of husking machines, commonly termed "shredders," equipped with shredder heads or cutter heads, or with combination shredder and cutter heads. The effectiveness of the machines was increased where special care was taken to apply sufficient pressure on the snapping rolls to produce a crushing effect and prevent long pieces of the fodder from being whirled through the head without being finely cut or shredded. Also, the speed recommended by the manufacturer should be maintained, and the machine should be fed evenly. Department of Agriculture Farmers' Bulletin 1662, Husker-Shredders in Corn-Borer Control, contains many suggestions and explanatory illustrations regarding the operation of husker-shredders under corn borer conditions.

It has been found that most of the borers that escaped death in the machine perish during the general practice of storing the shredded material, feeding it to livestock, and using the residue as bedding, which is finally trampled into the manure.

This method of disposing of fodder is strongly recommended, and its use in the corn borer infested areas should be greatly extended.

Inasmuch as many live borers may drop from this machine directly to the ground or pass through with the shelled corn, not only is it necessary to clean up carefully around the machine, but it is very essential that all remaining trash be disposed of properly. Feed the shelled corn and fine trash to chickens or hogs. Burn all the rest of the trash gathered from around the machine after the shredding operation is completed; do not put such trash in the mow.

The Cutting Box Is Effective if Adjusted Properly

The cutting box has proved effective in killing borers contained in cornstalks, if adjusted so as to cut the stalks in pieces not more than one-half inch long. Ordinary adjustments that cut stalks into pieces from 1 to 4 inches long or more in length do not kill many borers and should not be used.

Feed Grinders and Fodder Mills, or Mealers, Are Effective

Machines that grind roughage into a mealy consistency are popular with many feeders who want to feed roughage in its most edible form and who wish to control the feed content by using a combination of hay, cornstalks, or other roughage, and grain ingredients. These machines are ideal corn borer weapons when the roughage is ground fine enough to destroy the borers. For corn borer control their use is practical and economical. Some farmers who have tractors may be interested in owning one of these mealers cooperatively with their neighbors.

Be sure to clean up properly around the machine after the grinding operation is completed. Unground trash lying around the machine or scattered between the mow and the grinder may contain live borers.

PLOWING DEEP AND CLEAN

Plowing under of infested cornstalks, stubble, and other corn remnants is limited to soils that are in a condition to permit clean plowing and the preparation of a satisfactory seedbed before the corn borer moths emerge.

Effective plowing for corn borer control depends on turning under the corn remnants and other trash so completely that none of it remains on the soil surface. It is essential, also, that the material plowed under should not be dragged to the soil surface by later cultivation before the moths emerge and that the soil surface should be cultivated or pulverized to close all large cracks and crevices.

The plowing under of infested material does not of itself kill the borers. Most of the borers crawl up to the soil surface sooner or later. Where the plowing has been done in a clean manner, however, many perish as a result of exposure to natural enemies, which include birds, ants, ground beetles, and various insect parasites and predators. If, on the other hand, the plowing has not been done cleanly, these borers upon reaching the soil surface bore into any fragments of a corn plant (fig. 23) or weed that may be left on the surface, and with this protection they are able to complete their development to the moth stage.

The choice of the plow and attachments, and the previous treatment, if any, of the stalks or stubble can be left to the judgment and experience of the farmer, provided it is kept in mind that the stalks, stubble, and other material must be turned under cleanly and not brought to the soil surface by later cultivation.

The depth of plowing for corn-borer control is not important, *provided all infested material is covered completely to such a depth that it will not again be brought to the soil surface by later cultivation or weathering*, to act as a shelter for the borers crawling on the surface. In order to insure proper coverage, however, and to reduce the possibility of the plowed-under material being again dragged to the surface, plowing to a depth of at least 6 inches should be adopted if soil conditions permit.

The time of plowing is not important as far as the actual destruction of the corn borer is concerned. For instance, if the stalks are plowed under late in the summer, or early in the fall, or in the spring, most of the borers contained in the stalks crawl to the soil surface soon after the plowing. If the stalks are plowed under late in the

fall most of the borers remain inactive in the stalks all through the winter and then crawl to the soil surface after the soil warms up the following April or May. In either case it is important that they find no refuse on the surface in which to hide. Where soil conditions permit fall plowing, the necessity for deep and clean plowing is particularly important as a safeguard against erosion and the frost-heaving of material previously plowed under which sometimes results from shallow plowing under certain soil and weather conditions.

Plowing Methods Should Be Improved

The plowing methods now commonly used in many localities infested by the borer should be improved. Poor or ordinary plowing

Figure 23.—European corn borer in a small piece of cornstalk on a plowed field. This fragment (natural size) illustrates the necessity for clean plowing.

allows many pieces of cornstalks, stubble, husks, weeds, leaves, and other refuse to remain on the soil surface, thus providing shelter for many of the borers that crawl to the surface after being plowed under. This allows them to change into moths and multiply. For this reason either poor or ordinary plowing not only does not control the corn borer but in many respects is worse than no effort whatever, because a poorly plowed field (fig. 24) creates a condition that is difficult and expensive to clean up by other methods.

The skill of the farmer in doing a good job of plowing is as important, within reasonable limits, as the size or the type of plow used. Under favorable soil conditions 14-inch bottom plows equipped with attachments for covering trash give good results when properly adjusted. Specially designed 16-inch- and 18-inch-bottom plows now on

the market are well adapted for clean plowing and give good results, even when used in standing cornstalks or high stubble. Field experiments with these plows showed that when they are equipped with a rolling colter of proper size, a jointer, and a chain, or with the covering wires, as hereinafter described (fig. 25), practically all standing cornstalks and trash can be covered without previous treatment. With such equipment the stalks and trash can be turned to the bottom of the furrow so completely that the land can later be prepared for other crops without dragging the turned-under material to the surface.

An effective plow attachment of three wires to aid in turning under trash is shown in figure 25. A No. 9 galvanized wire gives good results. The wires should be about 12 feet long, attached as shown in the illustration, with the outer ends left loose. In operation the loose ends are

Figure 24.—A poor job of plowing. This type of plowing does not control the European corn borer, as the stalks left on the surface provide shelter for the borers that crawl to the surface after being plowed under.

caught by the furrow slice as it is turned over. In this manner the wires are held tightly to the top of the furrow slice by the weight of the soil on the buried ends of the wires, and this turns all trash to the bottom of the furrow.

The Bureau of Plant Industry, Soils, and Agricultural Engineering has developed a trash guide for attachment to ordinary plows (fig. 26) that in all tests to date, under widely varying field conditions, has given a very thorough and deep coverage to heavy growths of cornstalks, high stubble, and other plant refuse.

If the available equipment is not sufficient for plowing entire cornstalks or high stubble completely under, the stalks or stubble should be cut at the ground level, raked into windrows or piles, and burned as cleanly as possible, or some other effective treatment should be used. Any remaining parts may then be plowed under entirely.

Figure 25.—An effective use of three wires to aid in turning under cornstalks and other trash. The wires are about 12 feet long and the ends are left trailing.

Figure 26.—Clean plowing with the aid of trash guides. These aids to clean plowing can be easily made and attached to existing plowing equipment. (Photograph by Bureau of Plant Industry, Soils, and Agricultural Engineering.)

Circular 132 of the United States Department of Agriculture, Fighting the Corn Borer with Machinery in the Two-Generation Area, contains many suggestions and explanatory illustrations regarding plows and good methods of plowing, under corn-borer conditions.

BURNING INFESTED PLANTS

Burning is one of the effective methods of disposing of such infested cornstalks or other plant material as cannot be fed to livestock or plowed under cleanly. This method, however, may not be generally considered a good farm practice from the standpoint of returning as much organic matter as possible to the soil. Nevertheless, if control is to be achieved, the burning of cornstalks and other crop residues infested with corn borers seems justified and must be adopted when the material cannot be effectively disposed of in any other manner. The method of burning infested plants may vary in accordance with the prevailing farm practice. In case the corn is cut and shocked the problem is comparatively simple, since any surplus shocks can be burned where they stand or, if necessary, hauled to a suitable location and burned before moth emergence each year. This should include all cornstalks that have been used in building shelters for livestock, for thatching (fig. 27), windbreaks, or similar purposes, as well as surplus stalks stored for feeding, and cornstalks along ditchbanks and field borders.

If the ears are husked from standing stalks the problem of burning the stalks completely becomes more difficult. The main point to keep in mind, however, is that all corn remnants should be fed, plowed under, or burned. If burning is considered the best solution of the problem, several methods of procedure are possible. The stalks may be cut at or close to the ground level with any of the available types of stalk shavers or with a short-handled heavy hoe, in small fields in which such a method is practicable. When dry, the stalks should be raked cleanly into windrows or piles and burned completely, even though it may be necessary to resort to hand methods in raking stalks into the fires.

Many types of regular farm equipment and special tools have been used to cut off standing cornstalks or other infested plants. One of the most effective devices perfected to date consists of a simple home-made sled-type stalk shaver (figs. 28 and 29). This stalk shaver is ideally adapted for slicing stalks or high stubble off at the ground surface preparatory to raking and burning. Repeated tests of this device under a wide variety of field conditions have given excellent results, and its use for this purpose is recommended. Directions for the construction of this stalk shaver at home for a small outlay of time and funds are given in Miscellaneous Publication 142 of the United States Department of Agriculture, Construction of Sled-Type Cornstalk Shavers.

In the operation of cleanly raking the cut-off cornstalks, high stubble, or other plant material into windrows, the best success to date has been obtained with side-delivery rakes (fig. 30). The most satisfactory side rake yet obtained has four tooth bars, carrying closely spaced teeth, the speed of the cylinder remaining normal. On fairly smooth ground this rake has performed a satisfactory job of raking, even with heavy cornstalks.

Figure 27.—Wire corncribs thatched with infested cornstalks. These stalks are a source of infestation unless disposed of by burning or otherwise before the moths emerge.

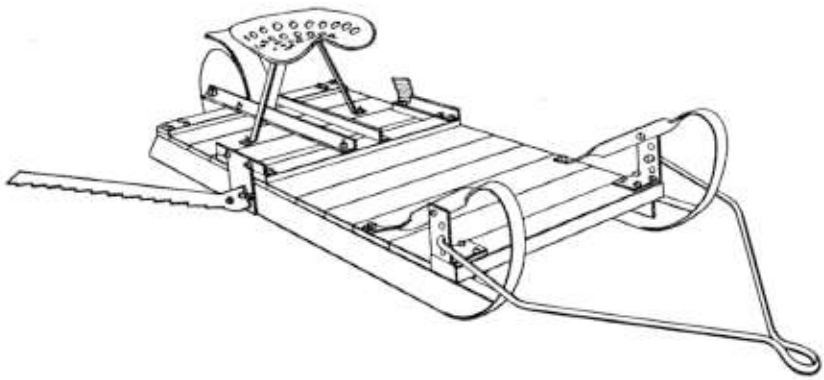

Figure 28.—A home-made stalk shaver for cutting off the stalks at the ground surface preparatory to raking and burning.

The common steel-toothed sulky dump rake can be used to rake trash into windrows preparatory to burning, provided that the soil surface is smooth, that the trash is fairly dry and clings together without shattering, and that the operator does not attempt to gather too heavy a load before dumping it. The special close-toothed sulky dump rakes now marketed by some manufacturers do better work on smooth ground than do rakes with the ordinary spacing of teeth. Usually, however, the sulky dump rake does not rake cornstalks cleanly enough to make plowing unnecessary.

Thus far the practice of hilling corn has proved to be a handicap in raking stalks cleanly. The practice of level cultivation must be resorted to more freely if raking stalks is to be effective in corn borer control.

Figure 29.—Cutting four rows of cornstalks with two stalk shavers drawn by three horses.

Figure 30.—Raking infested cornstalks into windrows and then burning them is an effective method of corn borer control if the infested stalks are cut at ground level, raked cleanly, and completely burned. The side-delivery rake used here is a four-bar outfit with closely spaced teeth and shields.

In order to emphasize the importance of disposing of small pieces of trash on the surface of infested cornfields, it should be stated that careful examinations of the surface of typical infested fields have shown that, on an average, 14 percent of the total original borer population were hidden in small pieces of cornstalks (fig. 23), corn husks, leaves, or weed stems left on the ground after it had been improperly cleaned.

Winter Poling Not Effective in General Practice

The practice of dragging sidewise a heavy log or railroad iron across the field to break off the stalks at the ground surface usually allows many of the stalks, though broken, to remain firmly attached, and this prevents a clean raking job. Experience has shown that only on rare occasions, when the stalks are frozen and there is practically no snow on the field, can poling be done so efficiently as to allow clean raking. Therefore winter poling preparatory to burning is not recommended as a corn borer control measure, and some type of stalk shaver should be utilized as a means of detaching the cornstalks from the soil.

DISKING STUBBLE OR ENTIRE STALK FIELDS IS NOT EFFECTIVE

Disking cornstalks or high stubble (fig. 31) in preparation for seeding to small grain or other crops is a very objectionable practice from the standpoint of corn borer control, except when followed by clean plowing. Disking not only allows a very high percentage of borers to survive, but the shade subsequently furnished by the growing grain affords protection from the weather to the borers contained in the trash left on the soil surface.

Rolling, "cultipacking," disking, or other types of harrowing are all methods of practically no value in corn borer control.

The present practice of direct disking of high stubble or cornstalks infested with the corn borer, as a preparation for small grains or other crops, must be discontinued if the pest is to be held in check and widespread commercial loss prevented. Disking should be preceded by the operations of cutting off the stalks at the ground level and completely disposing of them, together with all trash, by burning or otherwise.

CORN STUBBLE AN IMPORTANT SOURCE OF INFESTATION

It is plain that if the corn is to be cut, it should be cut as low and as early as possible and that all high-cut stubble should be disposed of by the recommended control methods.

The advisability of low cutting as a corn borer control measure in instances where this farm practice involves the cutting of corn is further emphasized by the fact that less than 1 percent of the original borer population of the field is present in the underground portion of the corn stubble.

Limited tests by Purdue Agricultural Experiment Station in Indiana have indicated that the use of a stalk pulverizer attached to a corn picker may prove to be a highly satisfactory method of disposing of the borer. A mortality of over 95 percent of the borers has been obtained from the use of such an attachment and the stalks are left in a condition ideal for forming a mulch, disking, plowing under, or baling for various uses.

DESTROYING BORERS IN HOME GARDENS

In many localities susceptible plants in many of the home gardens, especially small patches of sweet corn, often contain more borers per plant than do the large commercial fields. In these gardens susceptible vegetables, flowers, field crops, large weeds, and large-stemmed grasses growing in or along the margins of the sweet corn often con-

tain many borers as a result of migration of the borers from corn or from direct egg deposition by the corn borer moths or from both sources.

While these home gardens are usually small, the total acreage is sufficiently large to harbor large numbers of corn borers in many of the villages, suburbs, and cities in the older portion of the infested areas. Therefore, the clean-up of these home gardens becomes a part of corn borer control operations. The general procedure is similar to that described for large-scale control methods. In brief, the infested host-plant residues, such as cornstalks or stubble, flower stalks, vegetable stalks, weeds, and grasses, may be fed to any livestock in the vicinity, plowed or spaded under, buried by hand, burned, or completely disposed of by any combination of such methods as is most convenient, preferably late in the fall.

Figure 31.—Typical field of high stubble. This practice of high cutting must be stopped in areas infested by the corn borer, unless such stubble is disposed of by clean plowing, or other means, before the moths emerge.

CONTROL MEASURES THAT HELP UNDER CERTAIN CONDITIONS

INSECTICIDAL TREATMENTS

Insecticides are coming into rather extensive use for control of the European corn borer (*Pyrausta nubilalis* (Hbn.)) in market sweet corn and hybrid seed corn. With the advent of new materials and more efficient equipment for their application, the use of insecticides may eventually become practical even on sweet corn grown for the cannery and on field corn.

The most consistent control of the European corn borer in market sweet corn has been obtained through applications of a spray. The sprays that have been found most effective, considering cost and tolerance by the corn plants, are preparations of ground stems of *Ryania speciosa*, a rotenone powder (either ground derris or cube root), and a finely ground dust mixture containing not less than 25 percent of DDT with an inert diluent, such as certain clays.

In order to assure penetration of the spray deep into the whorl and between the leaf sheaths and the stalk where the young borers feed, and to obtain satisfactory control, it has been found necessary to include a spreading agent in the spray mixture. Spreaders are sold

in powder or liquid form and packaged under various trade names. Ordinary soap powders should not be used because of their tendency to burn the plants. The only spreading agents tested that have given consistently satisfactory results without plant injury are the sodium monosulfonate of butylphenylphenol, sold under the trade name "Areskap," and an aromatic monosodium sulfonate, sold under the trade name "Ultrawet." Other spreading agents are on the market, but the suitability of most of them for use in sprays for application to growing corn has not been determined. There is danger of injuring corn by the use of too much spreader. The use of an excessive quantity of this material should therefore be carefully avoided.

In ready-prepared water-dispersible powders containing 25 percent or more of DDT which are now available on the market, a spreading agent has been added by the manufacturer or processor. When directions on the package refer to the European corn borer, they should be followed carefully in preparing the final spray. The amount of spreader in the spray mixture should be one-third pound per 100 gallons of water, as indicated in the section "How to Mix Sprays."

Caution: **DDT is moderately poisonous to warm-blooded animals. Experiments have shown, however, that practically none of it reaches the kernels inside the husks of corn when they are treated according to the following instructions, and that roasting ears or mature grain from such plants may be eaten or fed to livestock with complete safety. On the other hand, light residues may remain on the leaves, stalks, husks, and silks. Such evidence as is now available indicates that the DDT residues left on the plants following the use of this insecticide in strict accordance with directions in this circular will not produce ill effects on livestock to which such plants are fed. However, some of the DDT may be excreted in their milk and deposited in the body tissues, especially in the fat. Therefore, until more information is available on the possible poison hazards to man from consuming the DDT residues occurring in milk and meat, the feeding of treated plants or portions thereof to milk animals or to livestock that is being finished for slaughter cannot be recommended.**

There is some evidence to indicate that the use year after year of DDT on crops in the same field, especially in light soils, may eventually cause accumulations of it in the soil that will be injurious to certain crops used in the rotation, such as tomatoes, cucumbers, and squashes.

How To Mix Sprays

In preparing the spray, a stock spreader solution should be mixed first. To do this, dissolve 1 pound of the spreader in 2 quarts of water and then add enough water to make 3 quarts (96 fluid ounces) of solution.

To mix 100 gallons of the spray proceed as follows: (1) Place a small quantity of water in a container and add 1 quart of the stock spreader solution; (2) add enough of the DDT powder to make ½ pound of actual DDT (finely ground dust mixtures containing not less than 25 percent of DDT with an inert diluent, such as certain clays, have been used very effectively), or 4 pounds of the ground derris or cube root, or 4 pounds of ground stems of *Ryania speciosa*, and stir

until the mixture is uniform and free from lumps; (3) add this mixture to enough water to make 100 gallons, while stirring thoroughly. Smaller or larger quantities of the spray may of course be prepared, but in so doing be careful to use the ingredients in the exact proportions indicated above.

How To Apply the Spray

Enough spray should be applied to penetrate the whorls, leaf axils, and other protected places where borers feed, and to cause run-off at the base of the plant. The quantity required for each application will range from about 100 to 200 gallons per acre, depending on the stand, size, and variety of corn.

A nozzle delivering a solid-cone, rather than a hollow-cone or other

Figure 32.—Directing the spray into sweet-corn whorls with an experimental horse-drawn, high-clearance, boom sprayer. (Photograph by Bureau of Plant Industry, Soils, and Agricultural Engineering.)

type of spray, has been found the most satisfactory for directing the insecticide toward the places where young borers are feeding.

On the corn in the early growth stages the spray should be directed downward into the whorl of leaves (fig. 32). When a power sprayer equipped with a boom is used, three nozzles per row of corn should be provided (fig. 33). After the ears begin to develop, the two outside nozzles should be lowered to not more than 1 foot below the center nozzle and turned slightly inward. The direction of the spray should remain downward and toward the ear, so as to treat thoroughly all places where the borers are feeding.

The insecticide should be constantly agitated in the sprayer during the application.

Compressed-air sprayers of the portable 3-gallon size (fig. 34) and the larger wheelbarrow type (fig. 35) have been found useful for spraying in home gardens and small acreages. Horse-drawn and self-propelled, high-clearance boom sprayers have given highly satisfactory control of the borer in commercial fields of sweet corn.

Figure 33.—Nozzle arrangements on an experimental, self-propelled, high-clearance, boom sprayer to give band of spray necessary for treatment of sweet corn. (Photograph by Bureau of Plant Industry, Soils, and Agricultural Engineering.)

Dust Treatments

A dust containing 5 percent of DDT mixed with talc or pyrophyllite has been found to provide a high degree of protection when applied at a rate per acre of 40 pounds of mixed dust. Satisfactory results have also been obtained with a dust containing ground stems of *Ryania speciosa*, or powdered derris or cube root, mixed with one of the diluents mentioned above. *Ryania* should be used at a concen-

Figure 34.—Hand application of insecticides for European corn borer control, by means of a 3-gallon portable sprayer.

tration of 40 to 50 percent in the mixed dust and the derris or cube mixture should contain not less than 1 percent of rotenone. Any of these dusts should be applied at the rate of 40 pounds per acre.

Applications to small plantings may be made with hand-operated bellows- or rotary-type implements, fitted with a single extension tube and nozzle. Power-operated, multiple-row dusters are more practical for larger acreages. They are available in high-clearance design and are equipped to treat four or more rows with two nozzles per row adjustable to various plant parts and heights.

When To Apply Sprays and Dusts

The first insecticidal application should be made when the corn borer egg masses in the field begin to hatch. Three additional appli-

Figure 35.—Hand application of insecticides for European corn borer control, by means of a "wheelbarrow" sprayer.

cations should be made at 5-day intervals, since egg laying and hatching continue during a considerable period, the insecticidal residues become diluted, and new, unprotected surfaces become exposed through rapid growth of the plant.

The time when the borer eggs begin to hatch varies from year to year, and from field to field. For this reason the insecticide applications must be timed by the first hatching within the field to be treated. Careful and timely observations must therefore be made in each field. When hatched eggs are found, or when eggs in which the black heads of worms can be seen, it is time to make the first application. Equipment and materials should be made ready well in advance of the time when they are likely to be needed.

TIME OF PLANTING

Where the borer has only one generation annually, field and sweet corn planted late in April or early in May usually sustains the worst corn borer infestation in a given locality. In contrast with this, plantings made the last week in May, or later, ordinarily escape severe infestation by the pest. However, tests with field corn have shown that the smaller number of borers on corn planted later cause a much greater loss per borer than do those on earlier planted corn. This greater damage per borer, plus the reduction in yield associated with later plantings, offsets to a great extent any advantage gained from late planting and suggests that plantings be made as late as possible only within the normal planting period adapted to the locality.

In any evaluation of the economy of late plantings of sweet corn to reduce borer infestations, the market gardener must consider the relatively higher prices prevailing earlier in the season, while the canner is confronted with the necessity of operating expensive factory equipment over a longer period of time to accommodate crops from large acreages. He must balance this factor, including increased inspection costs, against the value of late planting by the grower to decrease borer infestation and the consequent lessening of the danger of contamination in the canned product.

Under conditions where the pest multiplies twice each year, the first-generation borers tend to be concentrated in the corn planted early (late in April and early in May), whereas the borers of the second brood tend to be concentrated in corn planted after the last week in May. Plantings of field corn made the last week of May or later under one-generation conditions are only lightly infested by the borer whereas in two-generation areas these later plantings are frequently subjected to severe infestations from the second generation. These conditions indicate that early and late plantings of field corn should be avoided in areas where two generations occur and corn is exposed to severe infestations. Similar considerations with reference to time of planting under two-generation conditions also apply to sweet corn.

CHOICE OF CORN VARIETIES

None of the types, varieties, or strains of corn thus far tested under large-scale field conditions has shown any indication of real immunity from corn borer attack. It has been shown, however, that some strains of corn possess inherent characteristics which enable them to resist the borers better than other strains or varieties. The number of borers per plant at harvest, as compared with the number of corn borer eggs originally on the plants, is much smaller in some strains of corn than in others. Some of these resistant strains are being used in the production of commercial hybrids and in the corn-improvement programs of several States.

TRAP CROPS

Attention has been called to the fact that in any given area the earliest planted fields of corn, particularly sweet corn, usually suffer the heaviest corn borer infestation. This naturally suggested the use of a small area of very early planted sweet corn in fields intended for a main crop of field corn or late-planted sweet corn, to attract the corn borer moths and thus act as a trap crop. Such trap crops

must be destroyed or used for fodder early in the season. Actual attempts to apply the trap-crop method of control under field conditions, however, have failed to show reliable results from year to year. Trap crops cannot be depended on, but in a favorable season they attract many moths that would otherwise lay their eggs on the main crop of corn.

INEFFECTIVE MEASURES

TRAP LIGHTS

One of the first and most ineffective methods used in attempting to control destructive insect pests was the trap light, the theory being that since some moths can be attracted to the light they may then be destroyed. Although extensive efforts and much money have been expended in attempts of this nature, the use of trap lights as a method of control has seldom been successful with any insect pest. The trap-light method, in combination with various baits, however, was given a very thorough test in the course of the European corn borer investigations. Repeated observations with many types, kinds, and colors of lights showed that the number of corn borer moths attracted to such lights comprised less than 1 percent of the total number of corn borer moths in the vicinity. It is plain, therefore, that this has no value as a method of corn borer control.

ATTRACTIVE BAITS

Under experimental conditions corn borer moths have been caught in traps baited with a 20-percent molasses solution in water, and while such a trap has proved useful for technical purposes, it is not recommended as an effective means of protecting corn or other crops susceptible to infestation by the corn borer.

CATERPILLARS OFTEN MISTAKEN FOR THE EUROPEAN CORN BORER

Several kinds of common native caterpillars, "worms," or borers are often mistaken for the European corn borer and cause needless alarm. Some of these are similar in appearance to the European corn borer, and others, though very different in appearance, cause damage that often resembles the injury caused by the corn borer. Detailed descriptions and illustrations of many of these borers will be found in various Federal and State publications.

It is important that all corn growers outside the known infested area be on the lookout for the European corn borer. Therefore when any worms, caterpillars, or borers suspected of being the European corn borer are found, specimens should be placed in a tight glass vial containing alcohol or dilute formalin and be sent to the Bureau of Entomology and Plant Quarantine, Washington, D. C.

THE CORN EARWORM

On account of the similarity of the damage it does to the ears of corn, the corn earworm (*Heliothis armigera* (Hbn.)) (fig. 36) is very often mistaken for the corn borer. This insect is also known as the cotton bollworm, tomato fruitworm, and tobacco budworm.

The corn earworm, however, is not a true boring insect and usually confines its damage to the silks and kernels of the ear, whereas the corn

borer not only feeds habitually on the silks and kernels but also bores into the cob. Unlike the corn borer, the corn earworm very rarely bores into the stalks, although if the ears have not developed on young plants it often feeds on the leaves and in the growing tip, or "bud," of the plant. This injury sometimes results in broken-over tassels that at a distance resemble corn borer damage, but close examination will show that these tassel stems have not been tunneled. This characteristic serves to distinguish such injury from that of the corn borer. Late in the winter and early in the spring corn earworms are never present in the ears of corn or in the stalks, whereas corn borers may commonly be found in ears and stalks of corn at this time in areas in which corn borers are numerous.

The caterpillars of the corn earworm are about 1½ inches long when full-grown and vary greatly in color, ranging from tints of green, pink, rose, yellow, and brown to almost black. They may be beautifully striped, or spotted with brown, black, or yellow along the sides and back, or they may be entirely free from stripes or spots. In appearance they can be readily distinguished from the corn borer by the fact

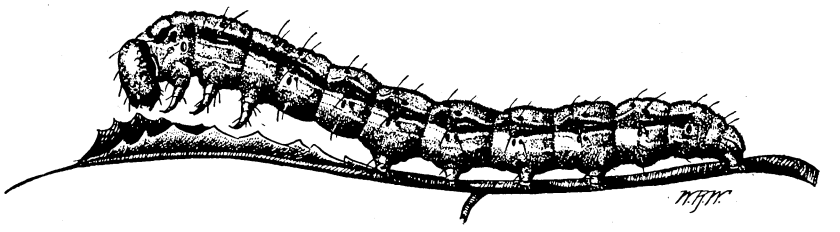

Figure 36.—Lateral view of larva of corn earworm. Not quite twice natural size.

that they are nearly twice the size of the latter. The hairs arising from the black tubercles, or warts, on the back of the earworm are much longer and stouter than those arising from the brown tubercles on the back of the corn borer. The castings of the earworm are coarse, wet, and foul, while those of the corn borer are more finely divided and usually dry. The corn earworm is widely distributed throughout the country.

THE STALK BORER

The stalk borer (*Papaipema nebris* Guen., form *nitela* Guen.) (fig. 37) often occurs in large numbers early in the summer in some sections of the country. They work habitually within the growing tip (heart) and stalk of young corn, and are frequently mistaken for the European corn borer on account of their habit of boring into the cornstalks. They also bore into the stalks, and infrequently into the fruit, of several other cultivated crops and flowers and weeds.

The young caterpillars of the stalk borer are very easy to distinguish from those of the corn borer, as they bear a dark-brown or purple band around the middle of the body, and several conspicuous brown or purple stripes run lengthwise of the body. The corn borer does not possess these conspicuous bands or stripes. As the stalk borer becomes full-grown, however, these bands and stripes disappear, and the color becomes plain creamy white or light purple, and only inconspicuous markings are visible. The full-grown stalk borer is slightly

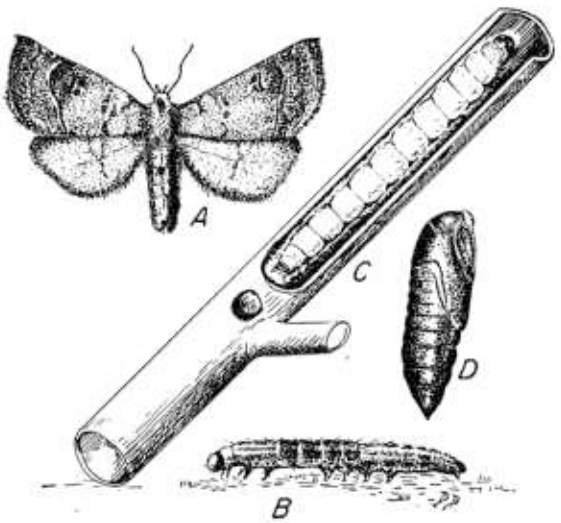

Figure 37.—The stalk borer: *A*, Female moth; *B*, half-grown larva or borer; *C*, full-grown larva in injured stalk; *D*, pupa. All somewhat enlarged.

more than an inch long and is much larger throughout than the corn borer. It is never found in cornstalks during the winter.

THE SMARTWEED BORER

The smartweed borer (*Pyrausta ainsliei Heinr.*) (fig. 38) is very frequently found in corn during the fall, winter, and spring. The appearance and work of this native borer resemble those of the Euro-

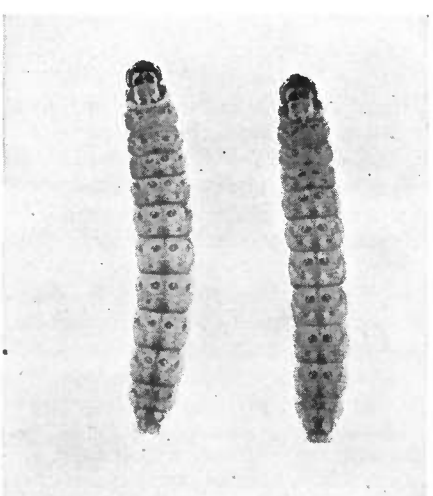

Figure 38.—The smartweed borer, very often mistaken for the European corn borer, as they are about the same size (compare with fig. 12). It is often found in corn plants which it has entered for shelter. Twice natural size.

pean corn borer so closely that it is very difficult to distinguish between them. The smartweed borer usually feeds within the stems of smartweed (*Polygonum* spp.), but it commonly bores into the stalks of corn and other plants when seeking winter quarters. It is practically harmless to corn.

It is known to be very numerous throughout the eastern part of the country, and many reports of European corn borer occurrence have been due to the presence of the smartweed borer.

The caterpillars of the smartweed borer are about three-fourths of an inch long when full-grown, slightly smaller than the corn borer, and less robust. They are always slate-colored or gray when full-grown, and in the living state they bear a very fine, faint line of darker color running along the middle of the back, whereas in the living corn borer this line is decidedly broader and very conspicuous. Except for these differences and one or two microscopic distinctions discernible only by an entomologist, these two kinds of borers have the same appearance when full-grown. On hatching from the eggs the small caterpillars of the corn borer have black heads, while those of the smartweed borer have pale amber-colored heads.

THE SOUTHERN CORNSTALK-BORER

In the Southern States, and especially in the South Atlantic States, the southern cornstalk borer (*Diatrae crambidoidies* Grote) is a common enemy of the corn plant, and owing to its habit of tunneling in the stalks of corn it may be easily confused with the European corn borer. The southern cornstalk borer, however, does not bore into the ears of corn, whereas this habit is characteristic of the corn borer. This southern pest habitually overwinters only in the roots of the corn, whereas the European corn borer not only winters in the stubble but may also be found in the stalks and ears of corn.

The caterpillars of the southern cornstalk borer are of two types—a summer form and a winter form. The summer form, when full-grown, is about 1 inch in length, with a dirty-white body thickly dotted with round or irregular dark spots, each of which bears a short, dark bristle. The head region is brownish yellow. The winter form differs from the summer form in that the caterpillar is more robust and is slightly shorter, while the spots referred to above are of nearly the same color as the body. Along the Gulf coast and on the Mexican border two distinct but very similar and closely related caterpillars sometimes attack corn. These are the sugarcane borer (*Diatraea saccharalis* (F.)) and the southwestern corn borer (*D. grandiosella* Dyar).

In recent years the southwestern corn borer has spread eastward and northward far into Texas, Oklahoma, and Kansas, and southern Nebraska. In fact, the ranges of the southwestern and the European corn borers may soon overlap in northeastern Kansas. The southwestern corn borer is not striped, and the spots on its summer form are darker colored and more prominent than those of the European corn borer. The winter or hibernating form of the southwestern corn borer is a uniform dirty white and is usually found in the extreme bottom tip of the stalk below the soil surface, whereas the overwintering European corn borer retains its characteristic markings and is generally found above ground in stubble, stalks, and ears of corn, and in other debris.

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